BIPV
Performance Failure Diagnosis

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29th European PV Solar Energy Conference and Exhibition, September 2014, Amsterdam, Netherlands

Parallel event: ***Grid-connected PV systems: Field testing, performance monitoring, and energy storage***

Frequently Asked Questions (FAQ) from BIPV system owners

Guy Leloux, Belgium
BIPV system owner
since 2008

- **How much energy can I expect to produce?**
- **Is my BIPV system performing well?**
- **When do I have to clean up my PV panels?**
- **Is this tree casting shading on my panels?**
- **How can I detect failures?**
- **What can I do in case of a failure?**
- **Can I trust my installer?**

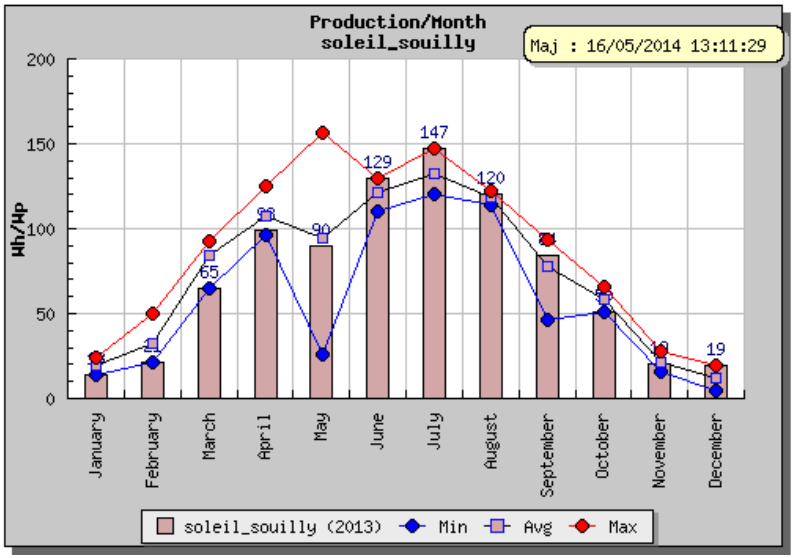
→ **Difficult to answer all these questions**

BDPV: A free Website used by 15,000 BIPV system owners in Europe

CONNECTION DATE : 09/2010
REGION : Lorraine
COUNTY : (55) Meuse
PEAK POWER : 2960 Wp
EXPECTED PRODUCTION : 2470 kWh/year
INVERTER : SMA - Sunny Boy 3000TL
SURFACE AREA : 21 m2
PANELS : 16xCP SOLAR - cps185w Building-integrated;
TYPE OF SALE : Sale of total.
INSTALLATION TYPE : Roof of a house.
SLOPE : 30° (optimum : 35) source PVGIS
ORIENTATION : 75°/South (optimum : -1) source PVGIS
ANNUAL LOSS IN COMPARISON TO THE OPTIMUM : 12.4% source PVGIS
INSTALLER : MA Geothermie

Year : 2013

☑ Min/Max et average for all years
☑ Scale production numbers to Wh/Wp.



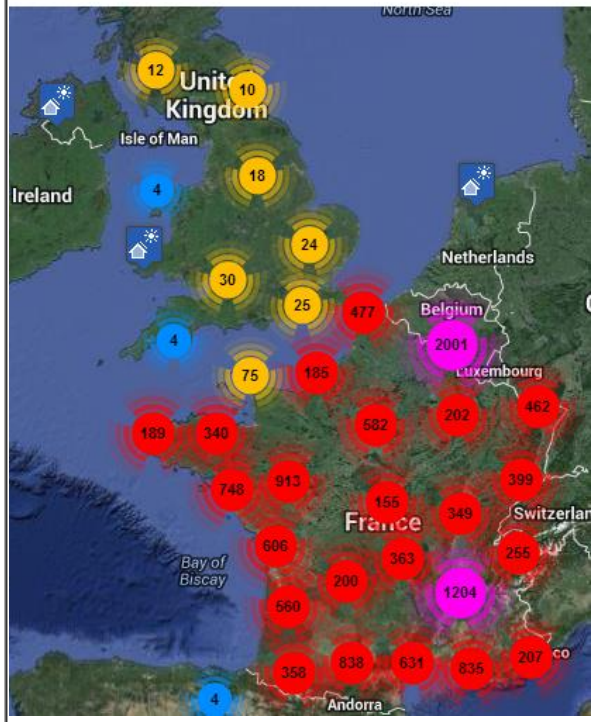
Since September 2010

Production of soleil_souilly
9324 kWh of electricity
9,324 MégaWattH of electricity

Nearby installations (maximum of 30)

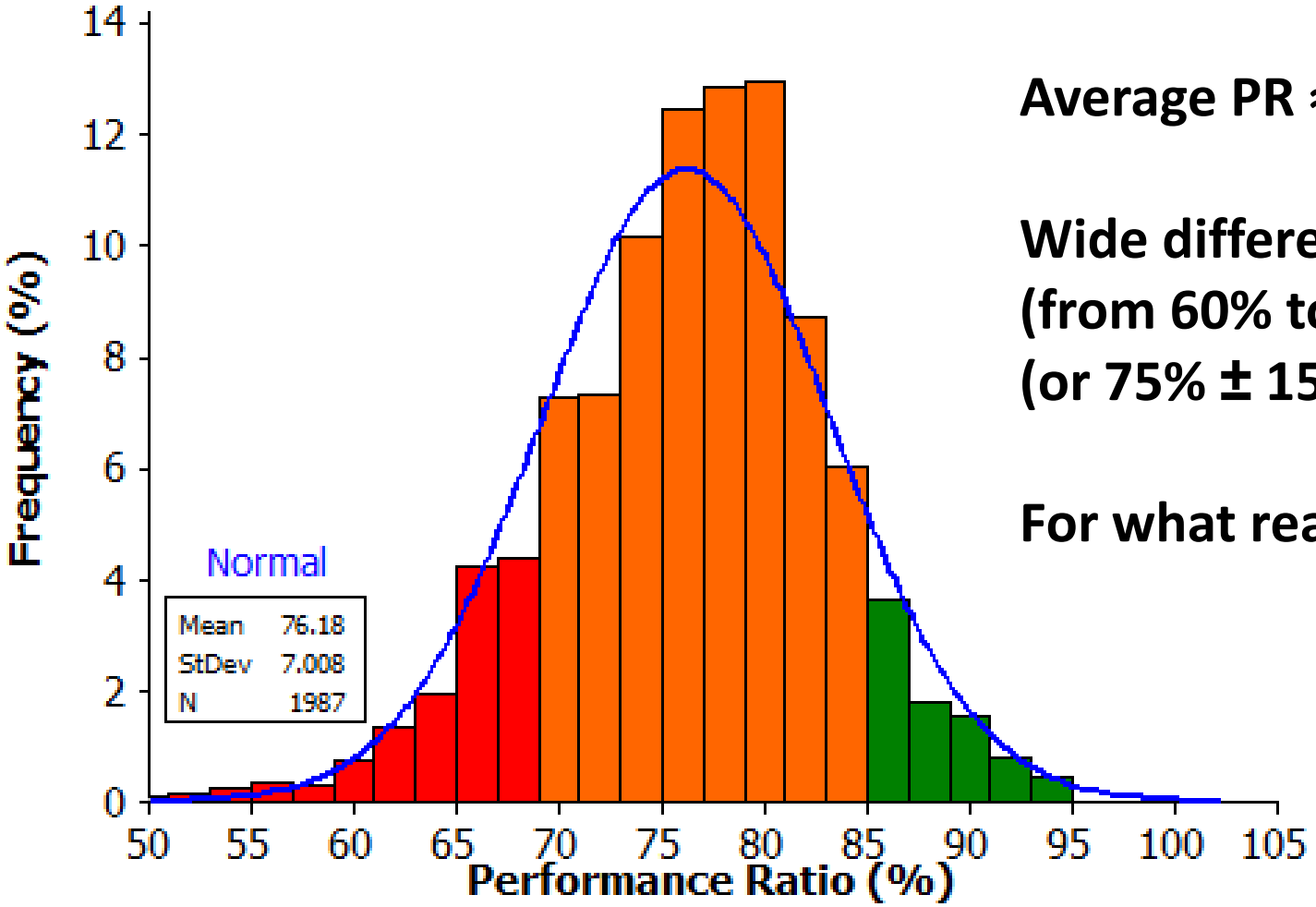
- 8km vince100
- 11km remi55
- 17km nanard55
- 18km nouvelhorizon
- 18km wandlaincourt
- 19km michtan55
- 23km ptitlouis55
- 23km wayne99
- 27km jpcoig55
- 28km nono57
- 30km grgrgr
- 30km liliane
- 31km joann
- 31km stef55
- 32km findus
- 34km bernard_55

BDPV
15,000 BIPV systems
1 energy data/month



Data Analysis?
Performance diagnosis?

On average, BIPV systems perform 15% below quality standards (Analysis of 10,000 BIPV systems from BDPV, France and Belgium)



Average PR ≈ 75%

Wide differences in PR (from 60% to 90%) (or 75% ± 15%)

For what reasons?

Results published in 2 scientific publications:

Review of the performance of residential PV systems in France, J. Leloux et al., Ren and Sust Energy Reviews, Elsevier, 2012

Review of the performance of residential PV systems in Belgium , J. Leloux et al., Ren and Sust Energy Reviews, Elsevier, 2012

BIPV professionals looking for good monitoring solutions

Rbee Solar

10,000 BIPV systems monitored

1 energy data/10min

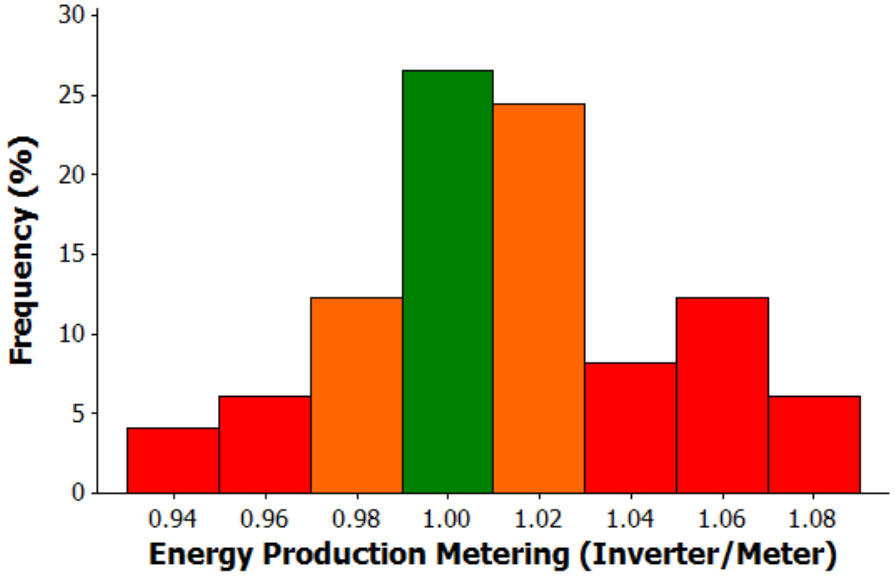
Data Analysis?

Performance Diagnosis?

Fault Detection?

Data Monitoring: Different systems … and costs

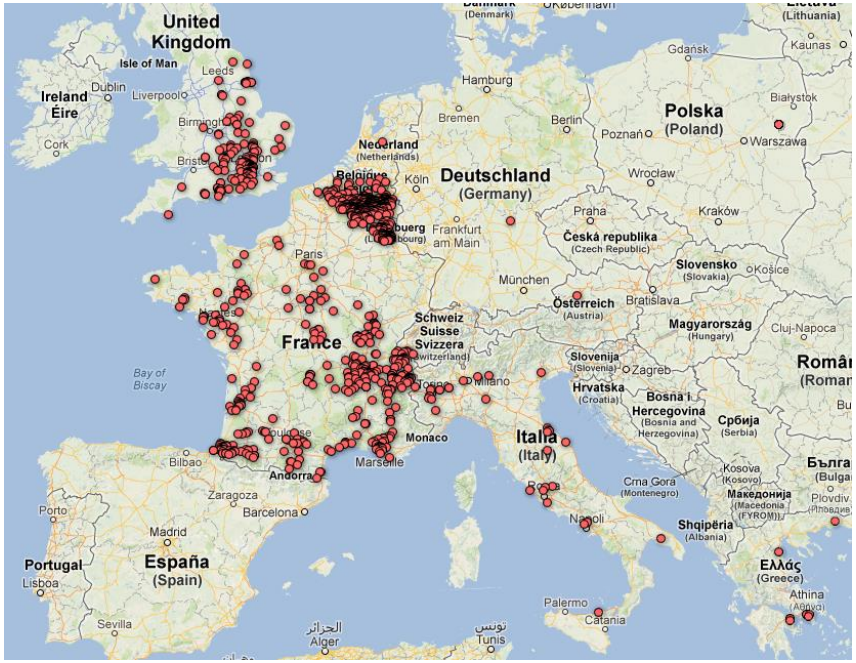
Material	Data	Measurement	Frequency	Error (%)	Cost (€)
Meter	Accumulated energy	Manual	1/month	0.5%	0€
Smart meter		Remote	1/10 min, 1/h, 1/day	0.5%	50-100 €/year
Inverter	Output Power, Current, Voltage, Others,… (DC+ AC)	Manual, Remote, Internet, Inexistent	1/10 min, 1/h, 1/day Never	1-10%	0-50 €/year

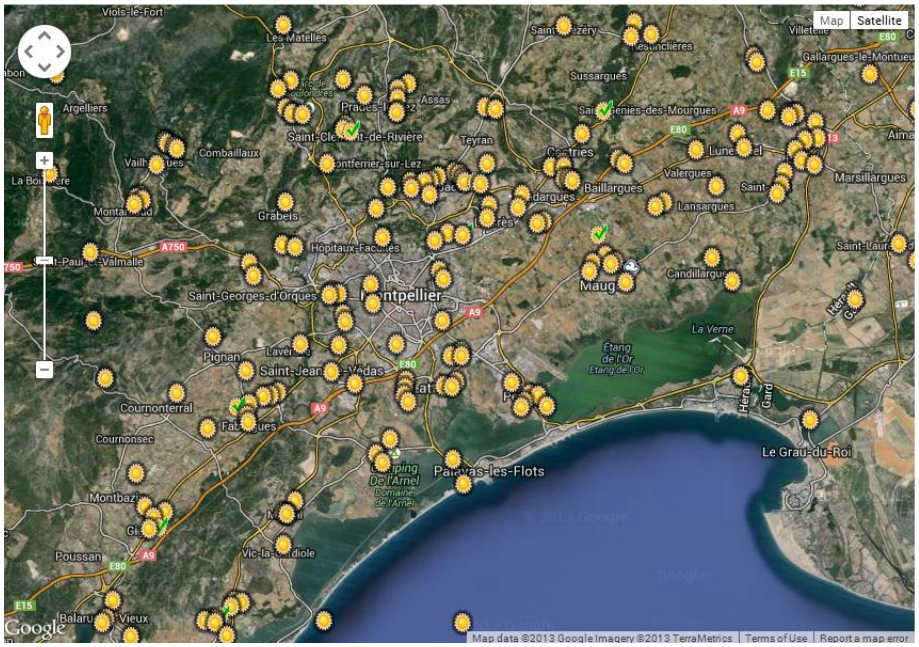


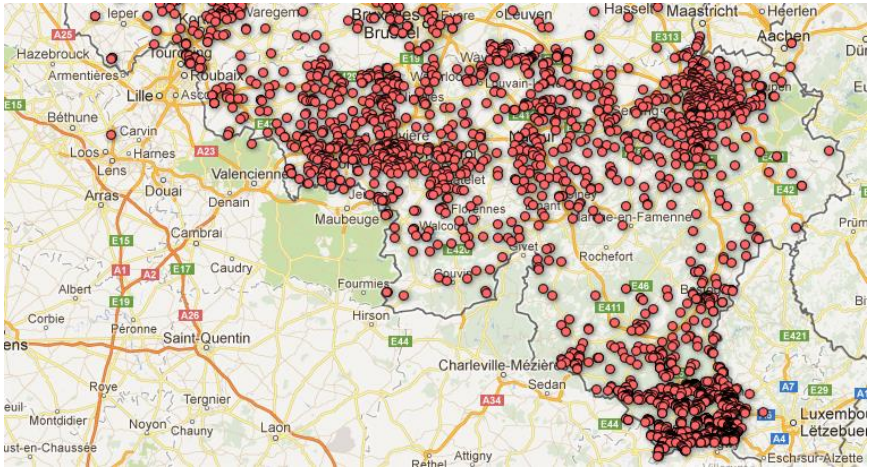
WebPV = Spin-off company (PVCROPS – UPM)
Core business: PV performance diagnosis and fault detection

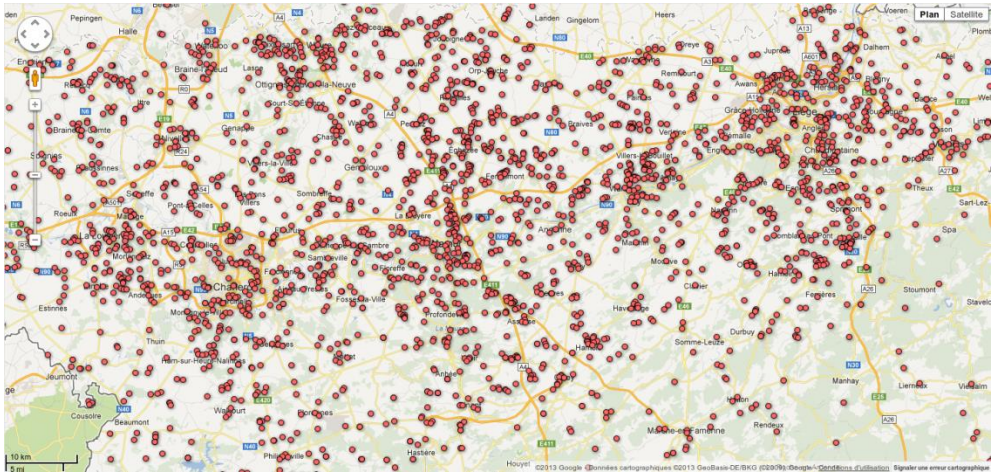
Demand Identified → **Scientific Background** → **R&D project** → **Spin-off Company**

Monitoring data analyzed by WebPV - UPM
BIPV: 25,000 installations; PV Plants: 100 MW

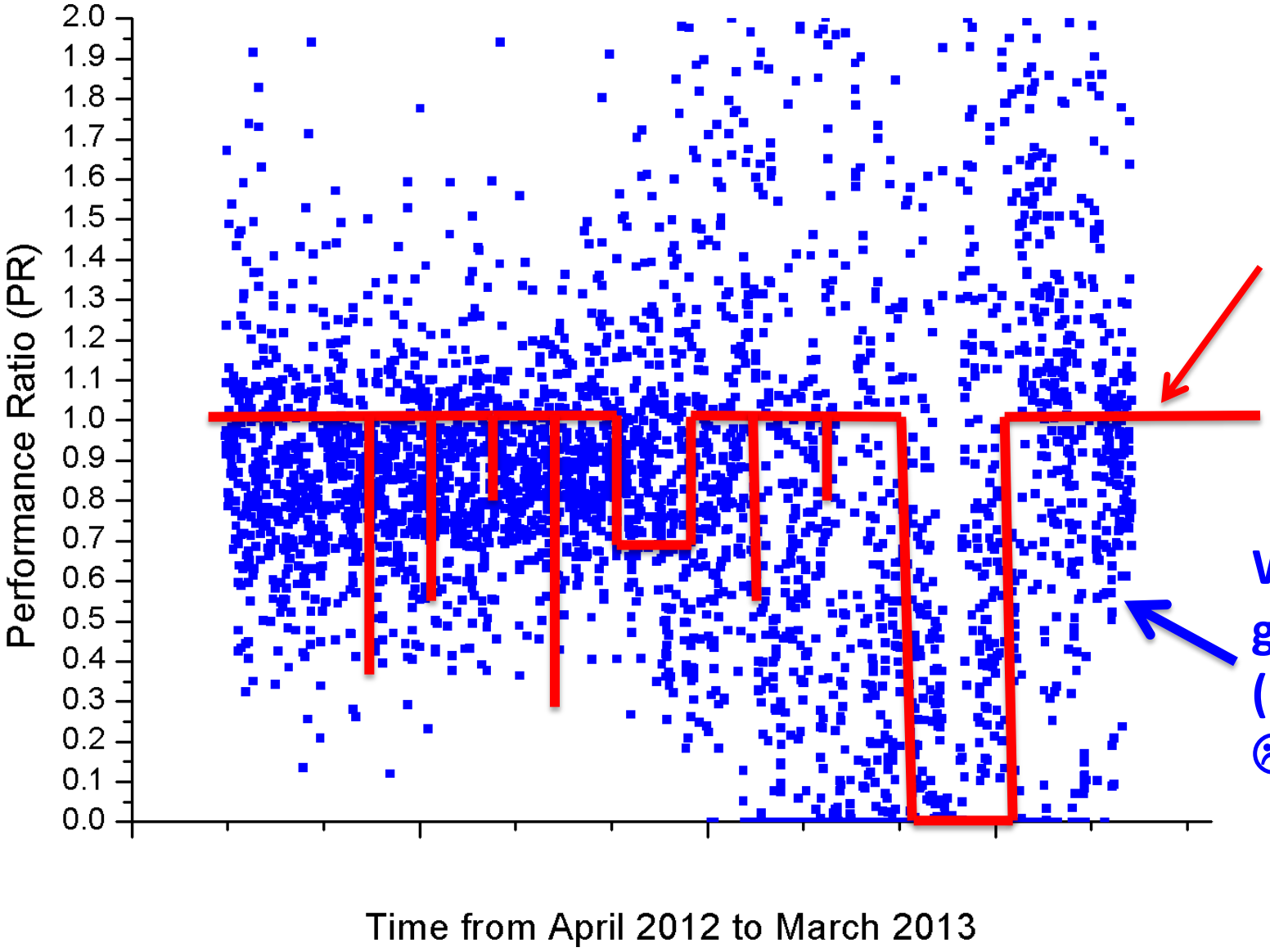






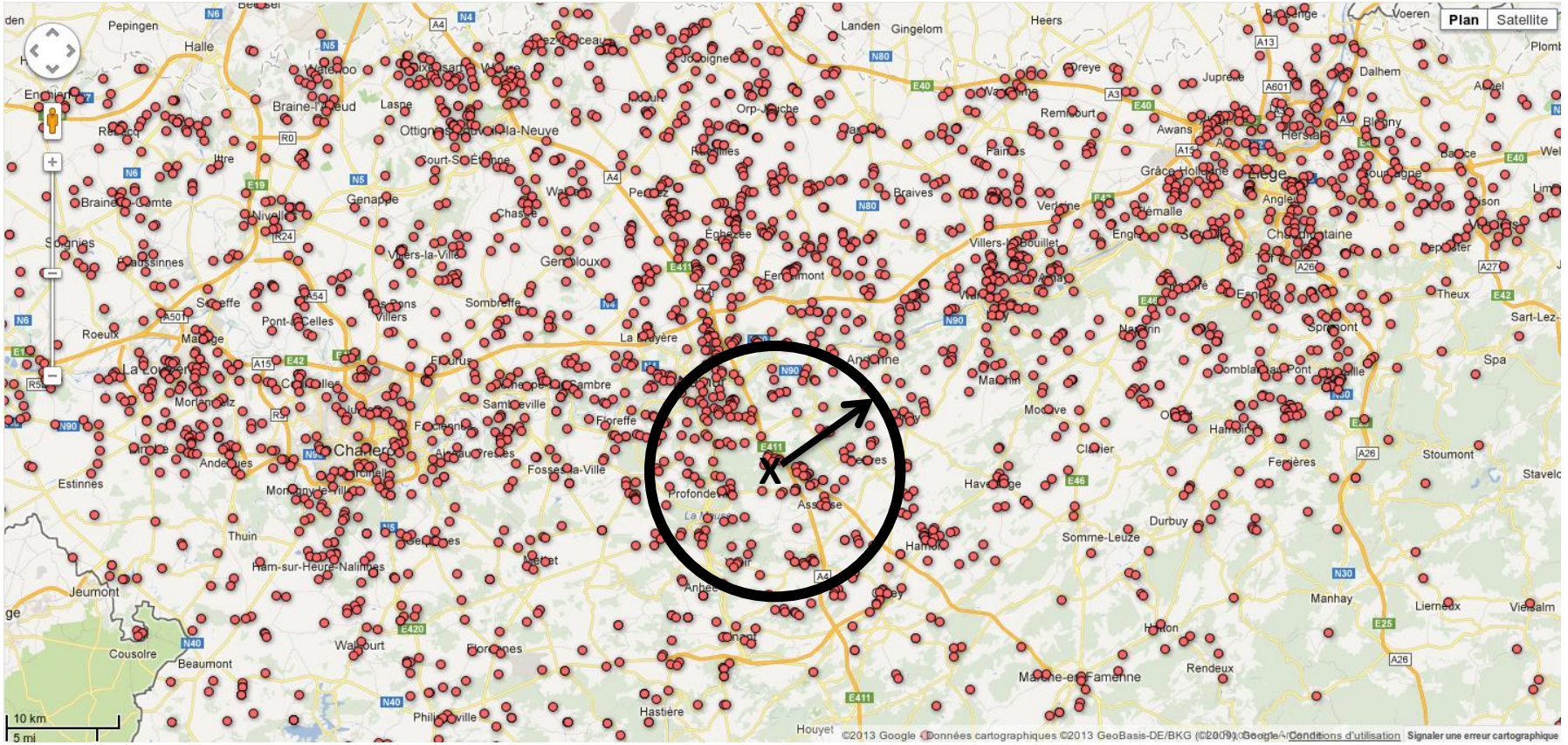


State of the Art = PR (Performance Ratio) = Poor fault detector ☹
WANTED: A good fault detector!!!



Novel fault detector: *Performance to Peers (P2P)*

P2P = (Performance of focus BIPV system) vs (Performance of its peers)

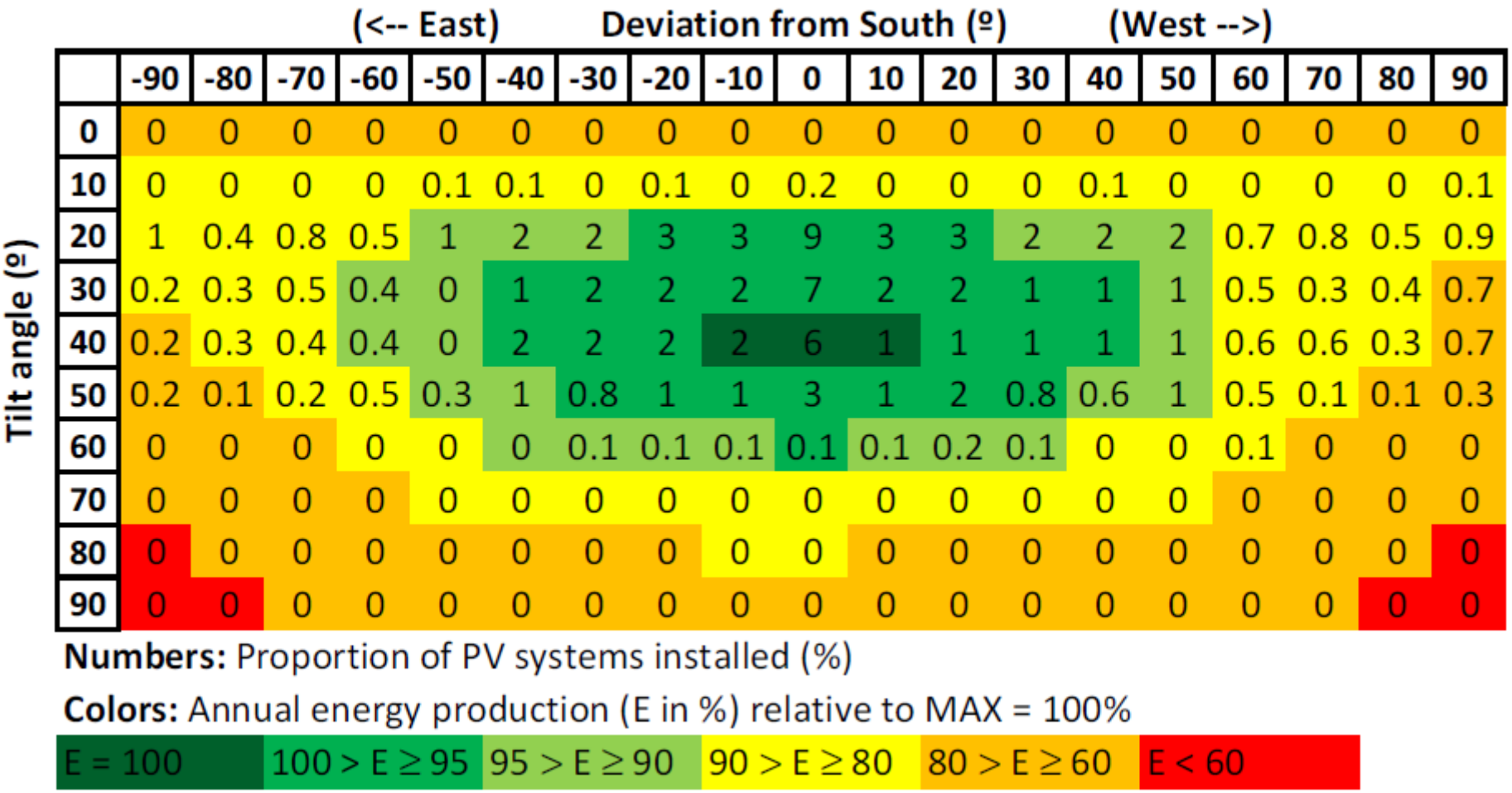


Technology patented
(Spanish Patent Nº P201430369)

$$P2P = \frac{E_{produced}^{Focus\ System}(T)}{E_{produced}^{Peer\ Systems}(T)}$$


HIDEY HO, NEIGHBOR

Orientation distribution of BIPV systems and related energy losses



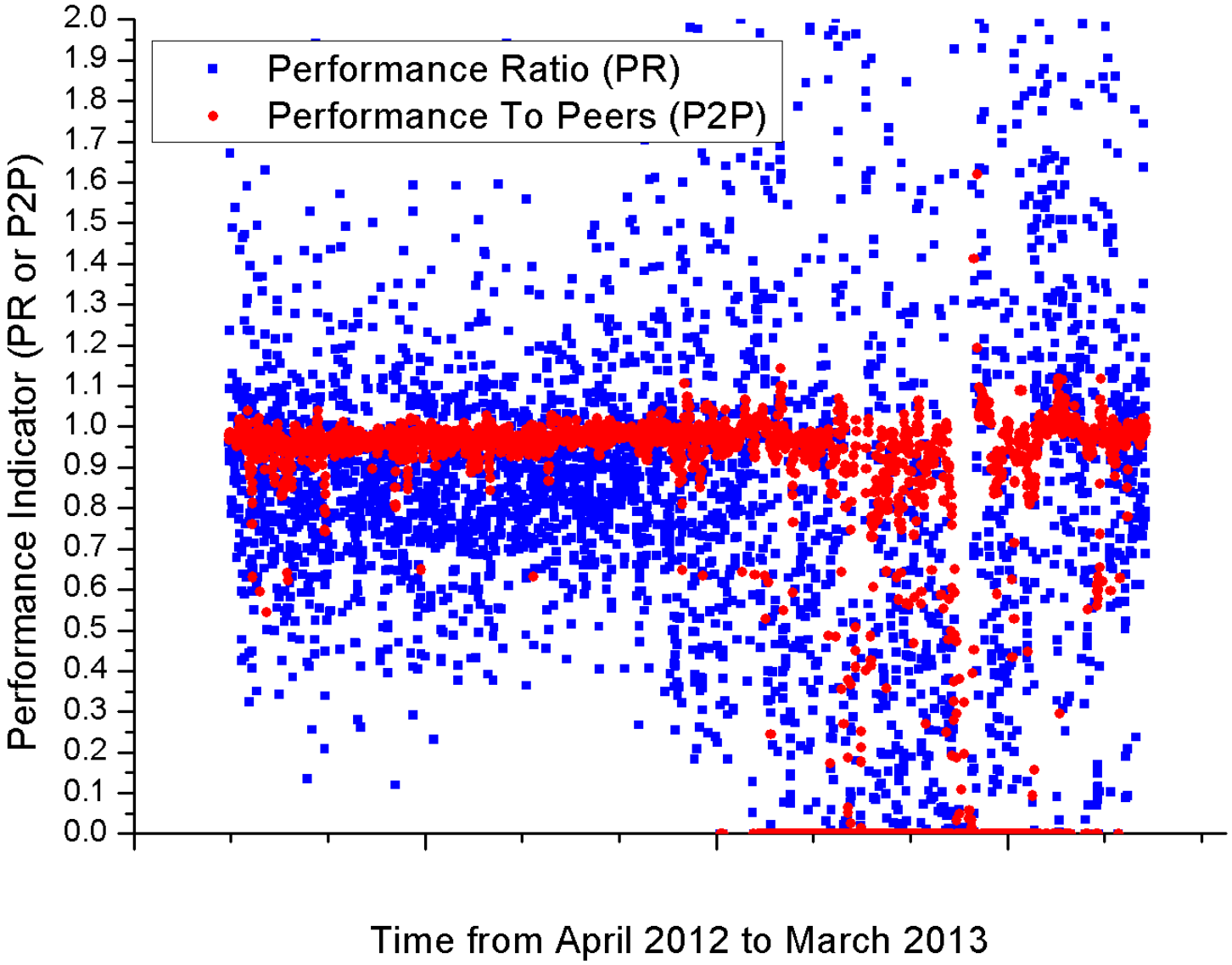
Tilt angle (º)	(<-- East) Deviation from South (º) (West -->)																		
	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0.1	0.1	0	0.1	0	0.2	0	0	0	0.1	0	0	0	0	0.1
20	1	0.4	0.8	0.5	1	2	2	3	3	9	3	3	2	2	2	0.7	0.8	0.5	0.9
30	0.2	0.3	0.5	0.4	0	1	2	2	2	7	2	2	1	1	1	0.5	0.3	0.4	0.7
40	0.2	0.3	0.4	0.4	0	2	2	2	2	6	1	1	1	1	1	0.6	0.6	0.3	0.7
50	0.2	0.1	0.2	0.5	0.3	1	0.8	1	1	3	1	2	0.8	0.6	1	0.5	0.1	0.1	0.3
60	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0	0	0.1	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Numbers: Proportion of PV systems installed (%)

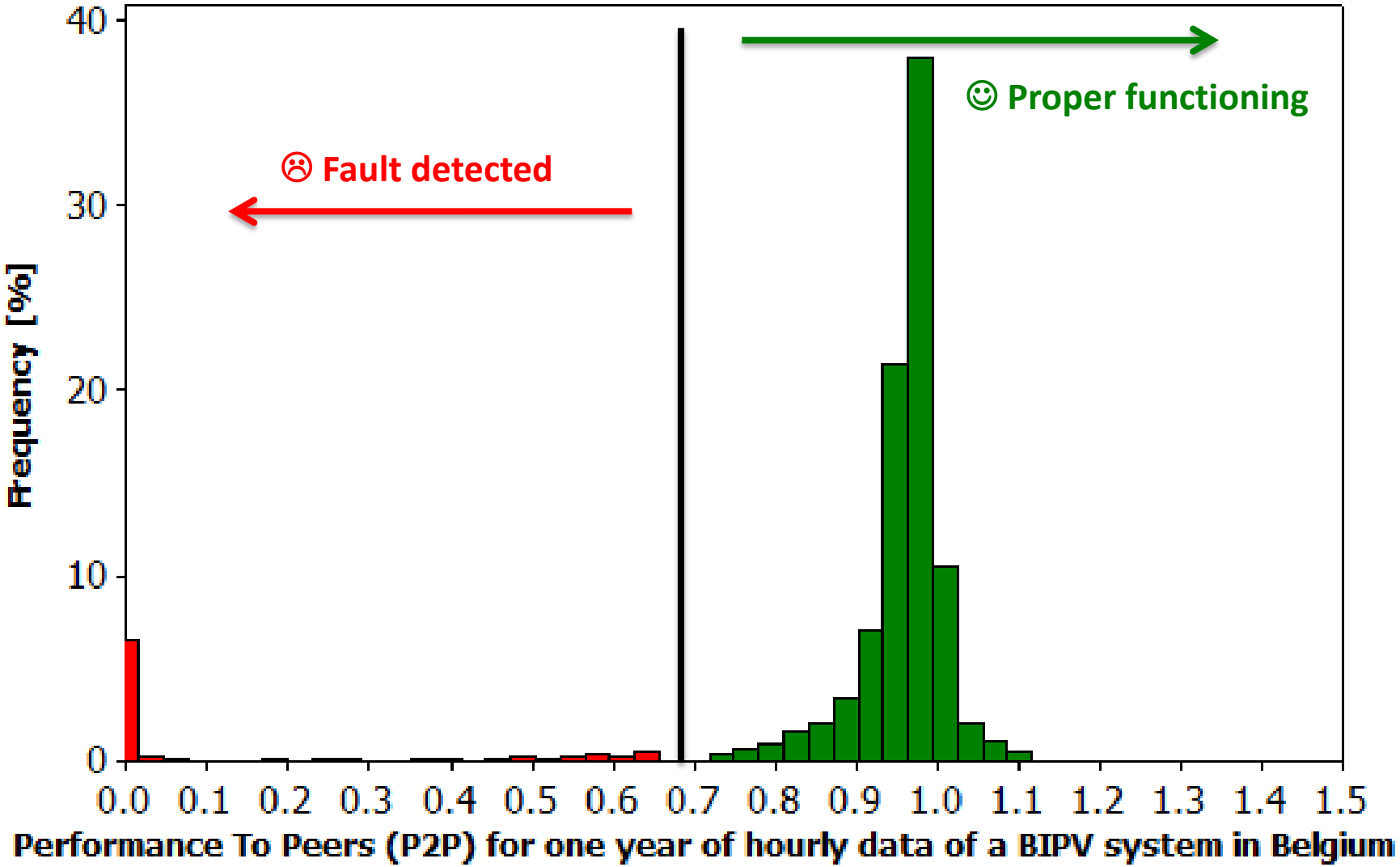
Colors: Annual energy production (E in %) relative to MAX = 100%

E = 100	100 > E ≥ 95	95 > E ≥ 90	90 > E ≥ 80	80 > E ≥ 60	E < 60

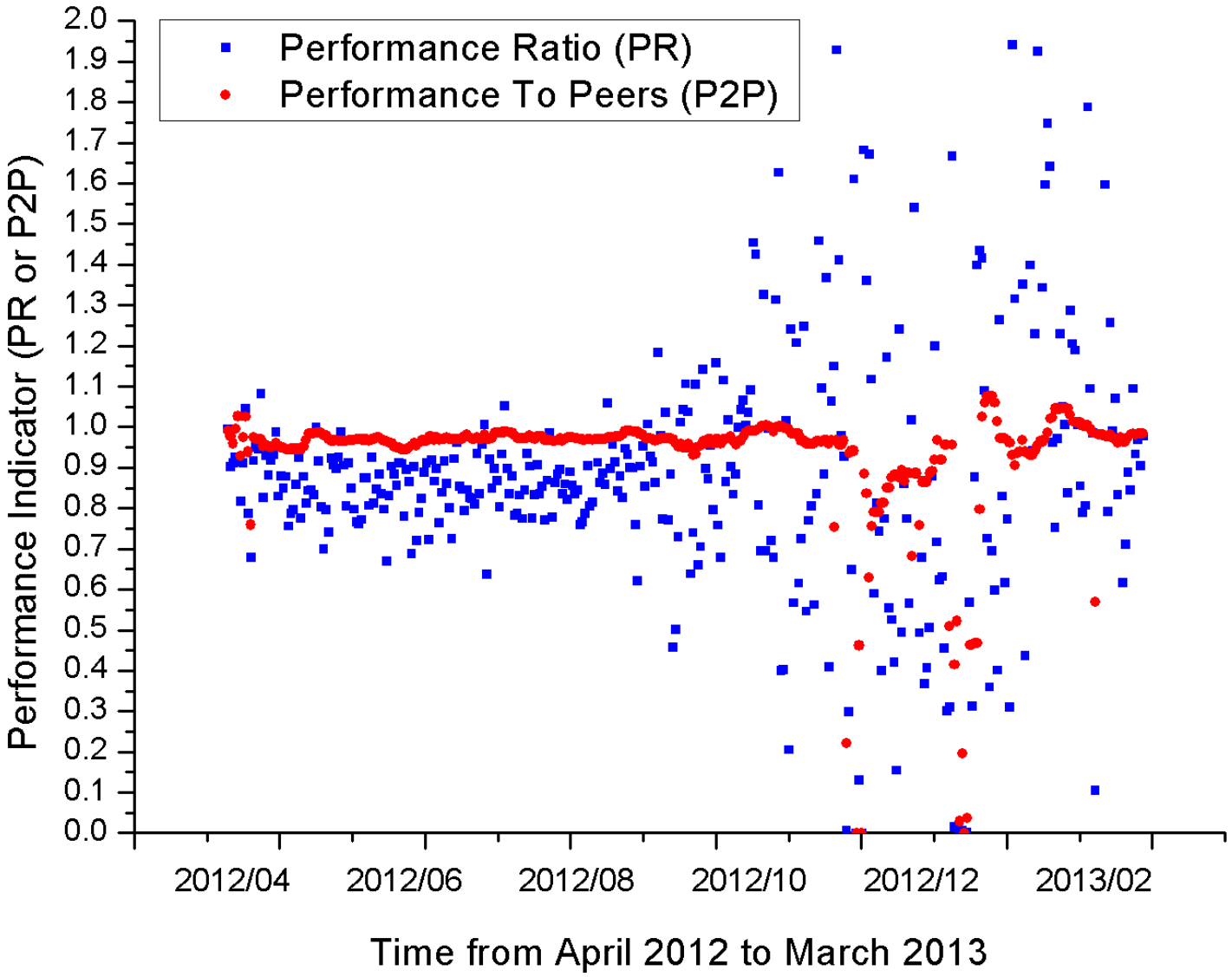
Performance to Peers (P2P) much more stable than Performance Ratio (PR)



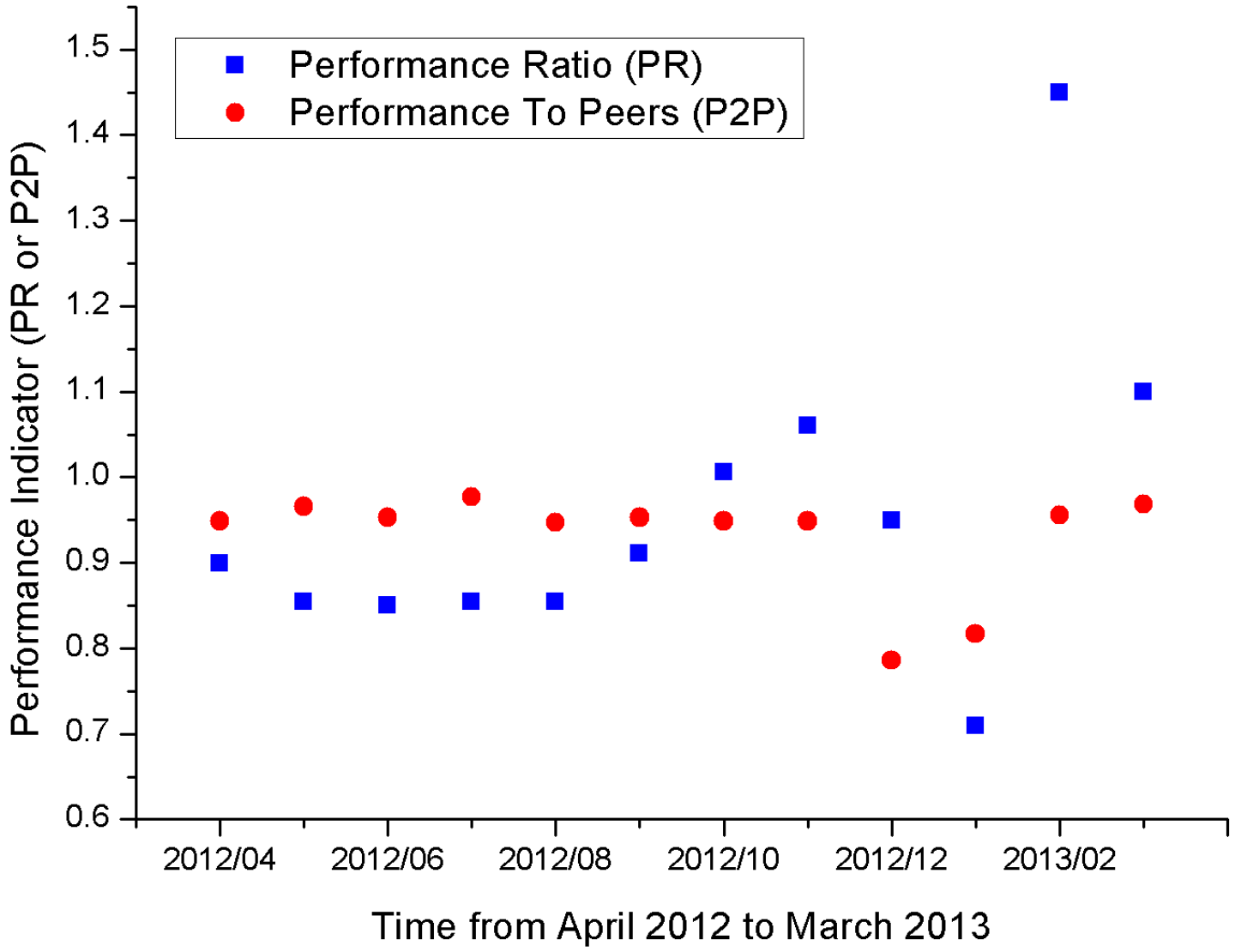
When P2P value is far from normal → Fault detected!



PR vs P2P (daily data)

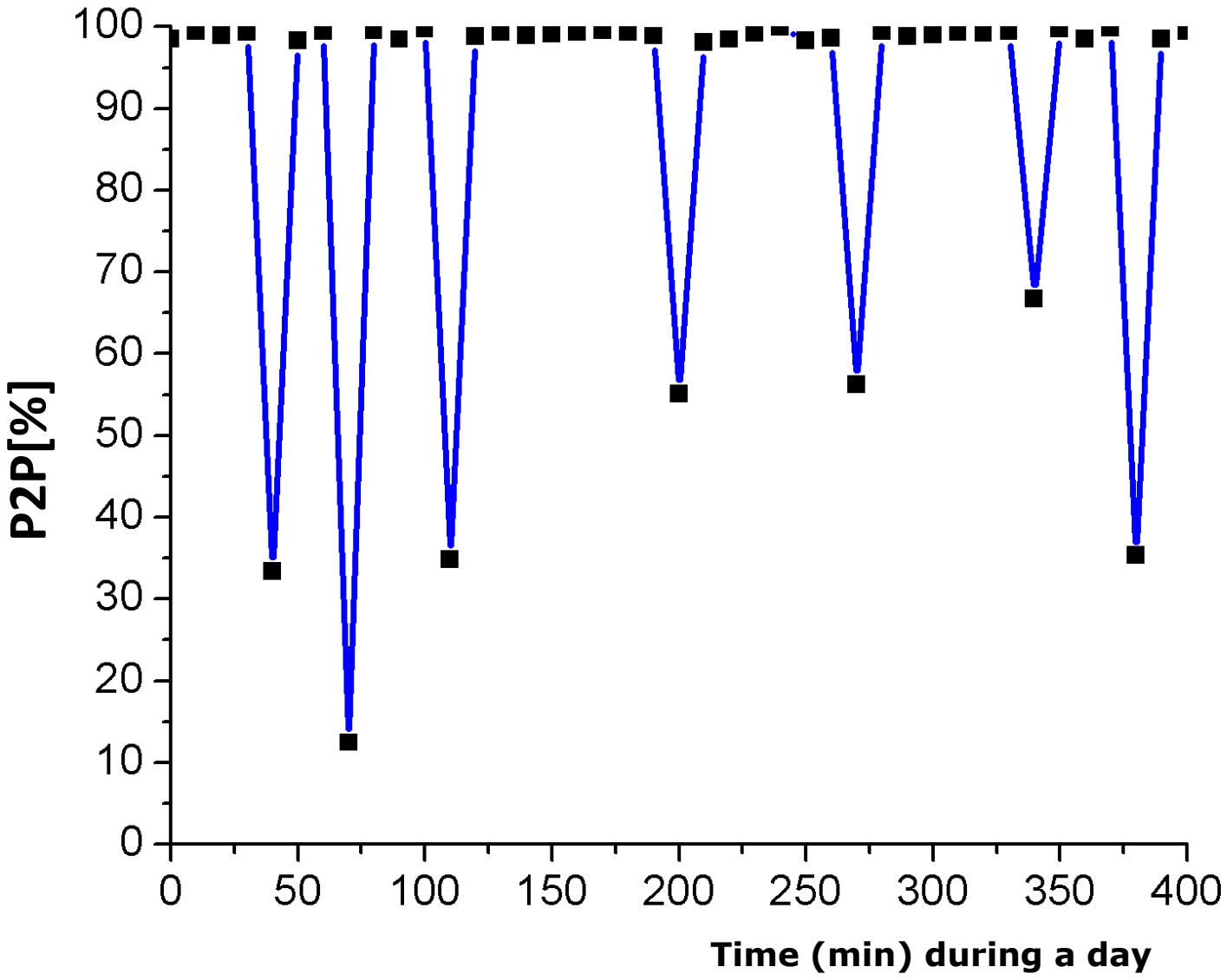


PR vs P2P (monthly data)

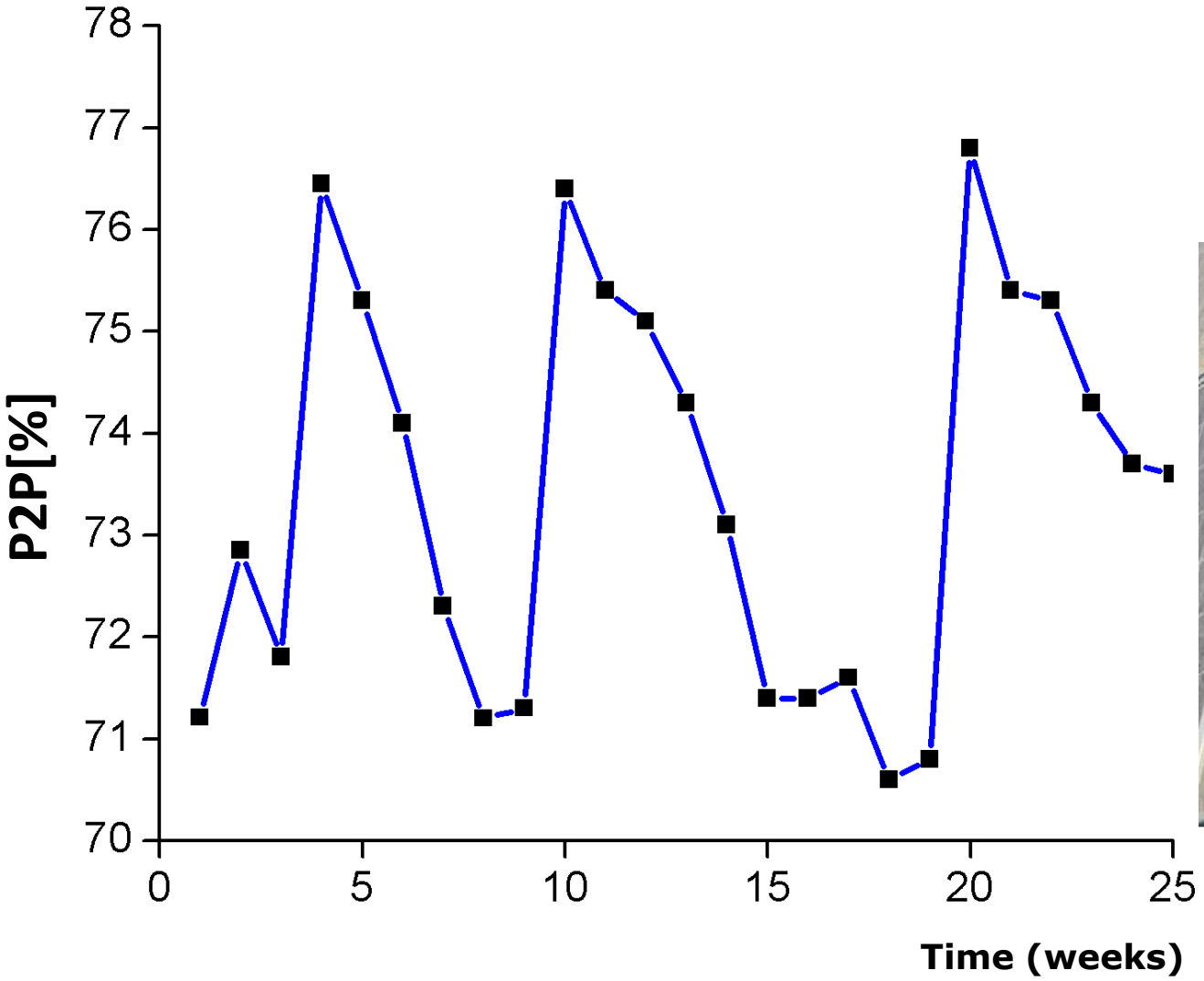



I
my neighbor.

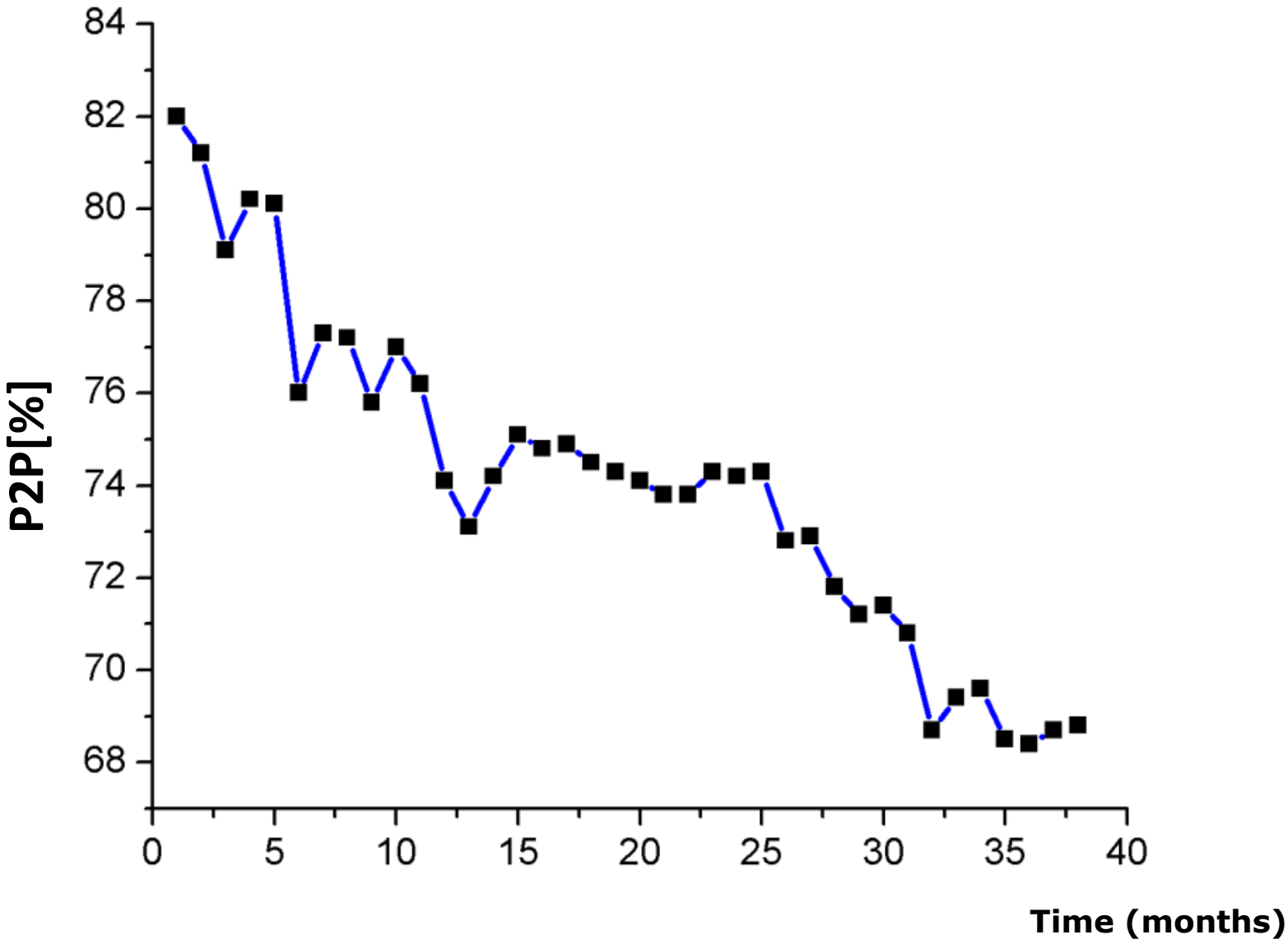
Fault diagnosis from P2P: Grid-inverter problems



Fault diagnosis from P2P: Excessive soiling



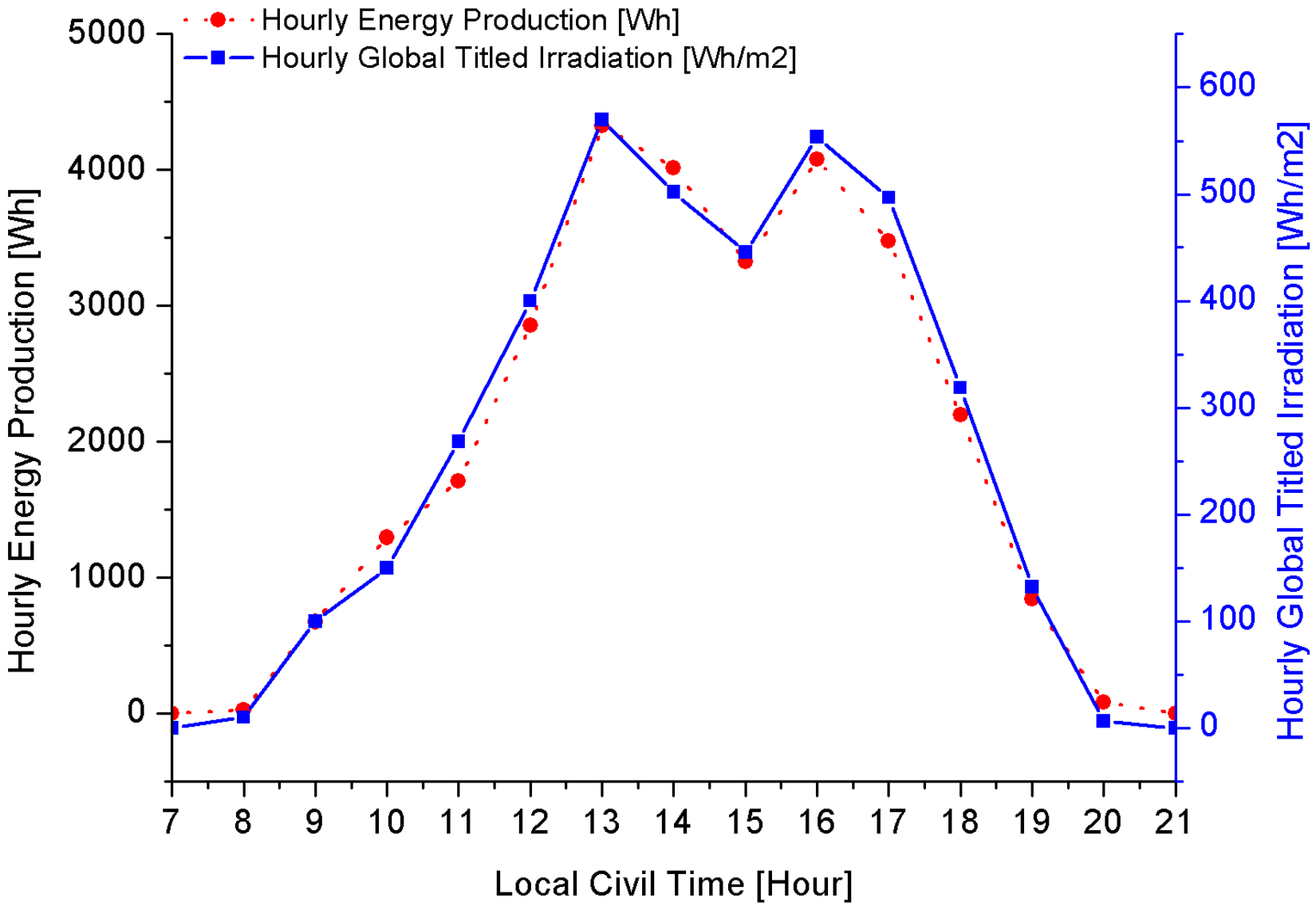
Fault diagnosis from P2P: PV modules degradation



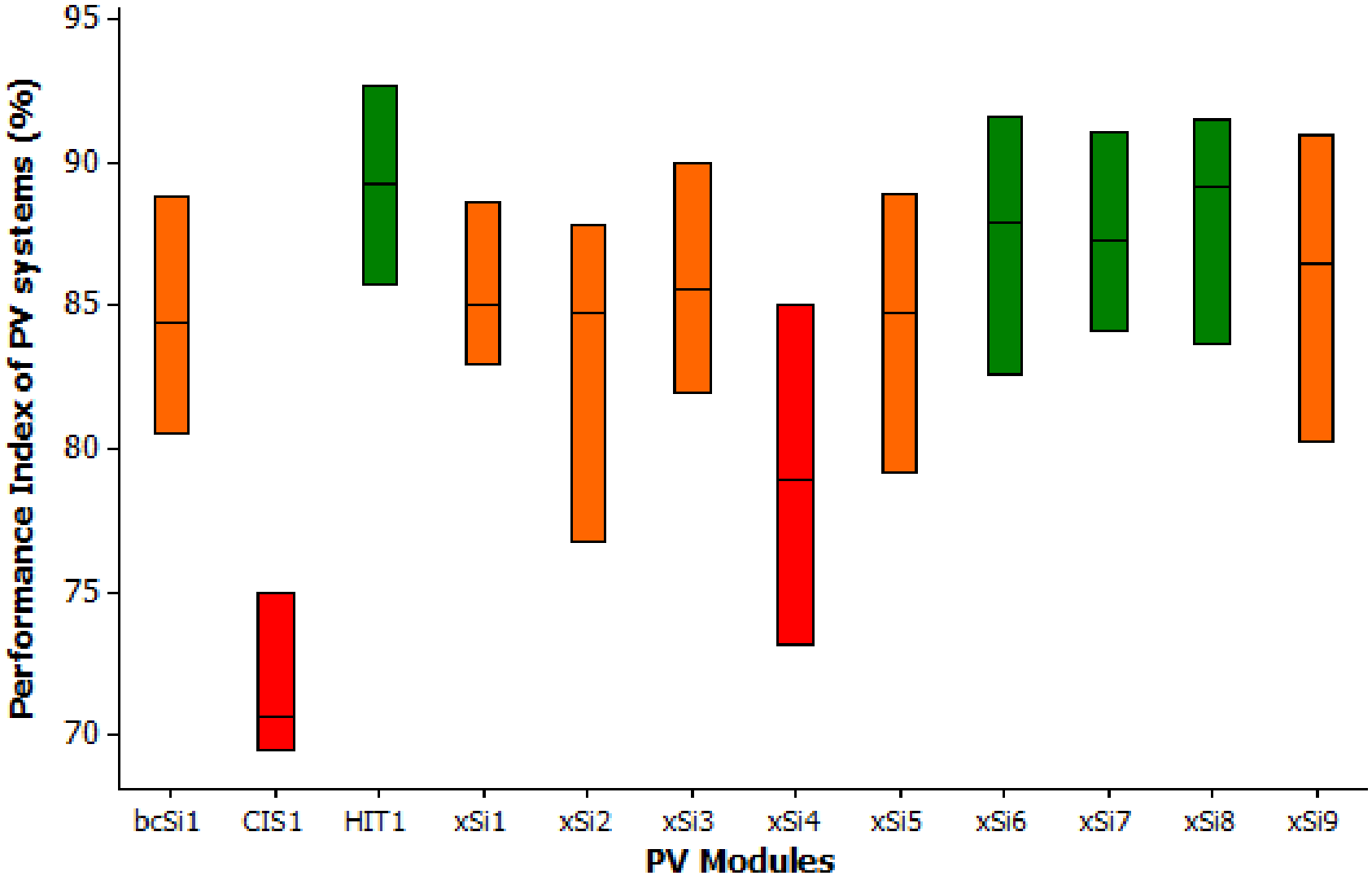
Quantification of energy losses due to faults detected by P2P

Installation ID	Detected failures	Energy losses (%)
211069313	1	0.10
211228133	1	0.10
211069307	1	0.10
210287006	1	0.10
210225602	1	0.12
210287091	3	0.17
211338662	1	0.24
211263097	2	0.33
210424083	13	**1.13**
211069267	19	**2.81**
211338680	17	**2.82**
210287089	30	**3.01**
211069304	24	**3.09**
211069276	35	**5.64**

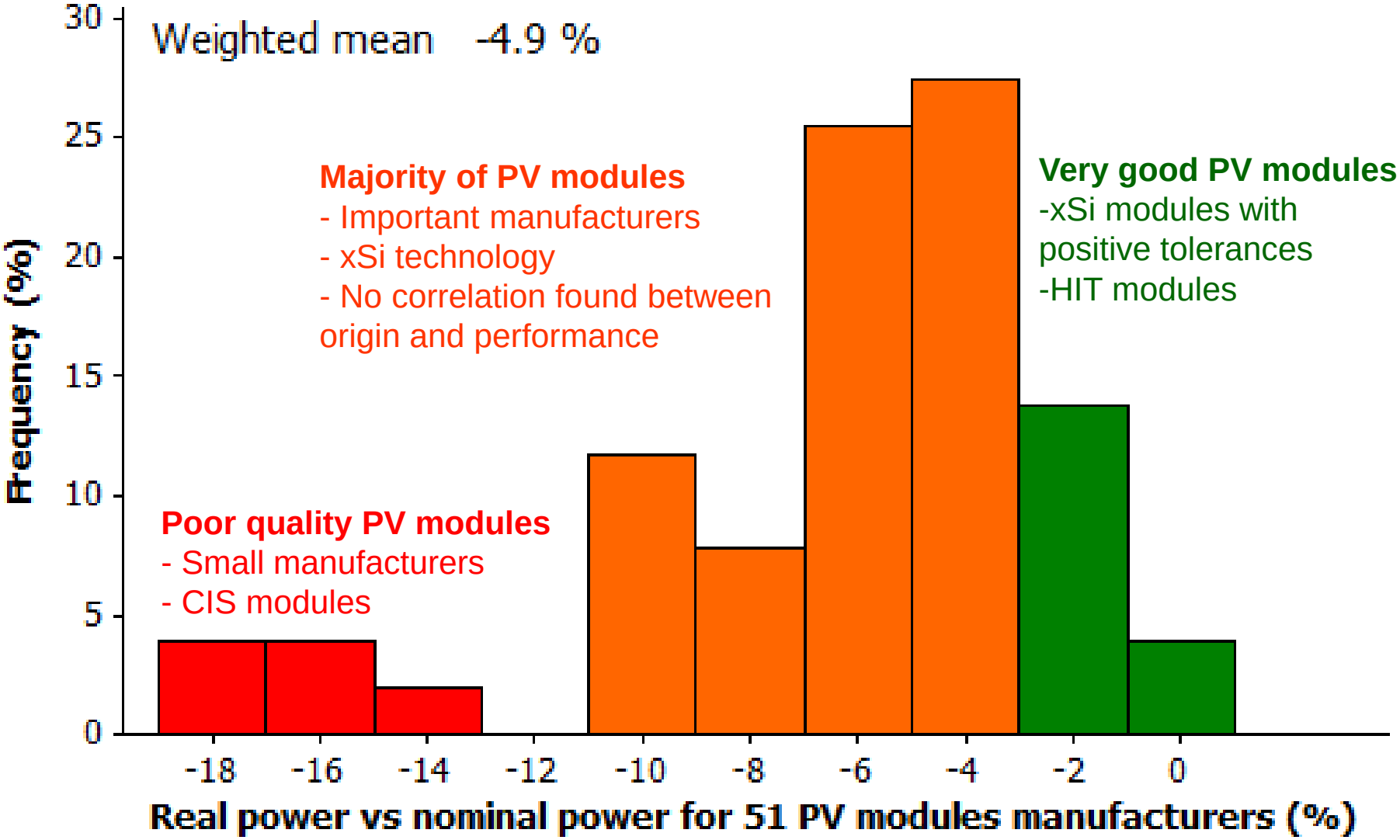
Need accurate solar irradiation data?
The energy produced by peer BIPV systems can also provide it!



We identified the main differences in performance between PV systems

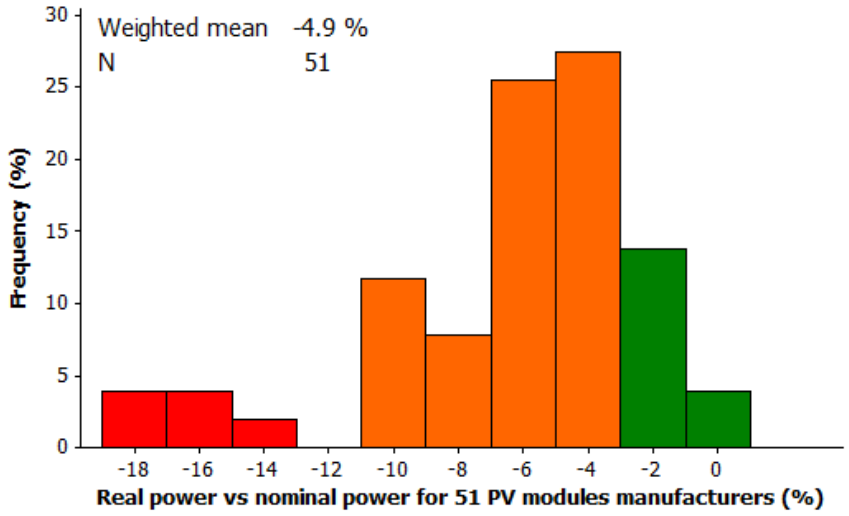


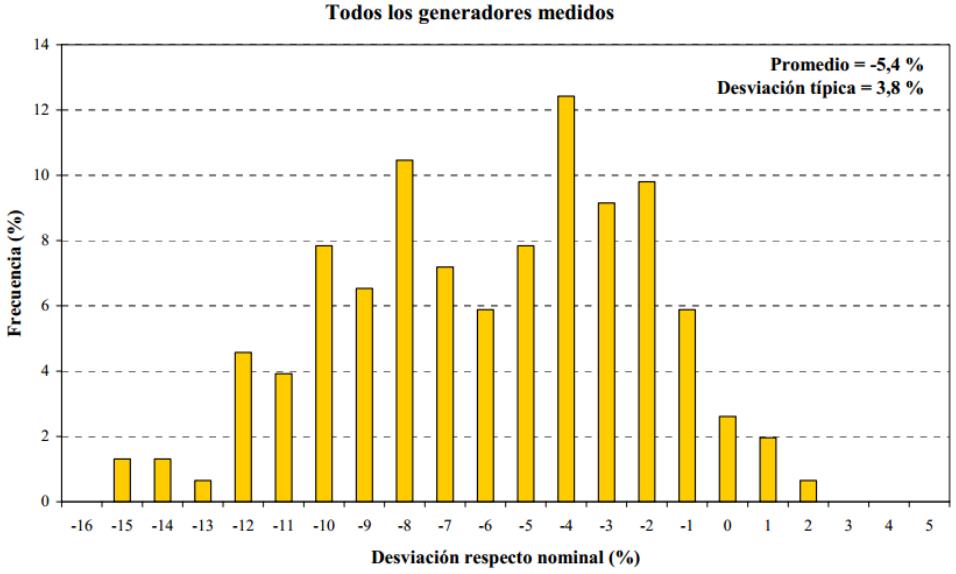
State of the art of PV modules:
Real power = (Contractual power – 5%)



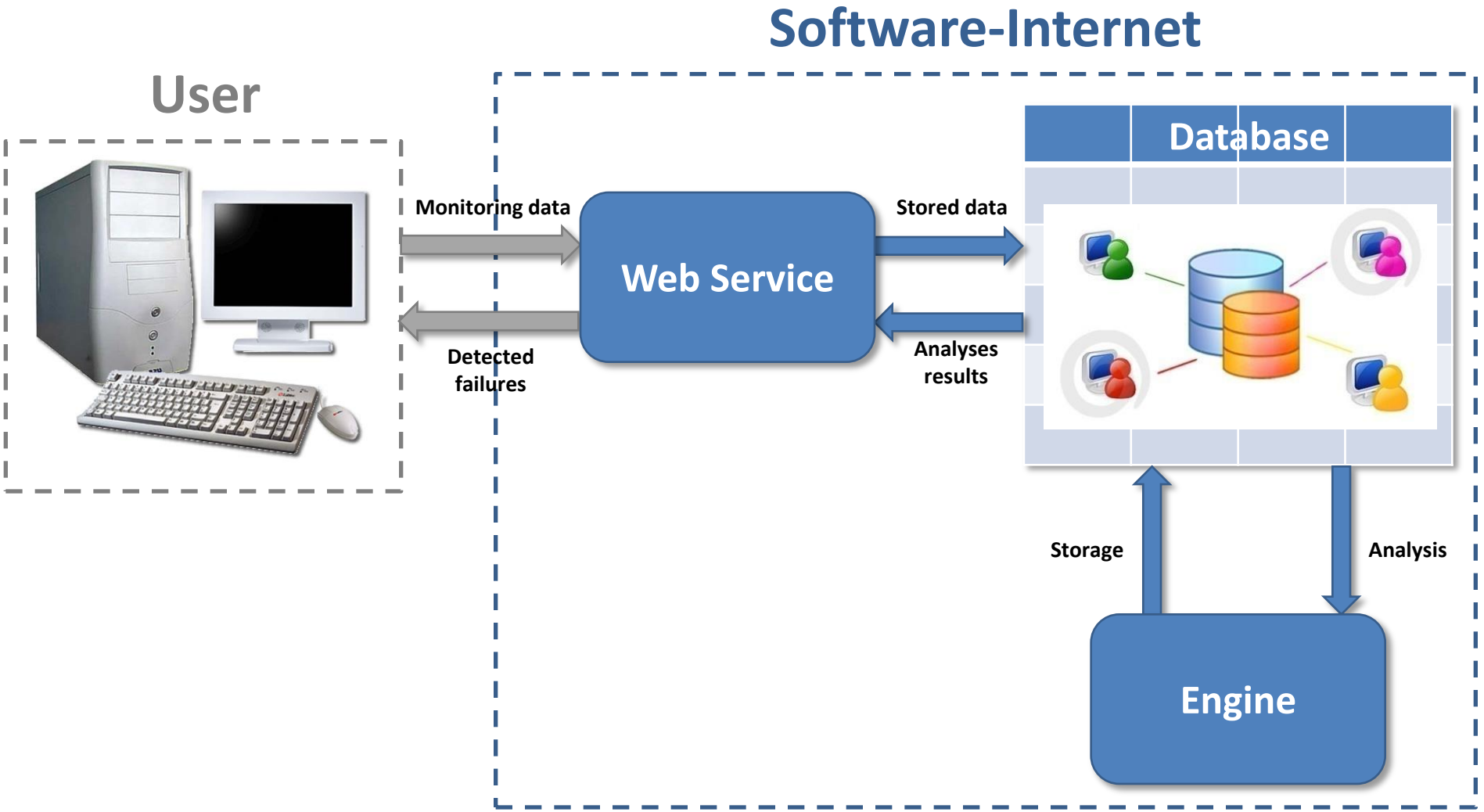
Results on BIPV in North of Europe
SIMILAR TO Results on PV plants in South of Europe

PV Module (Hidden names)	ΔP (%) [Statitics on BIPV]	ΔP (%) [In-field Meas.]	Diff (%)
PV1	-6.4	-7.1	**0.7**
PV2	-4.6	-3.1	**-1.5**
PV3	-10.7	-12.3	**1.6**
PV4	-1.3	-2.1	**0.8**
PV5	-6.1	-4.7	**-1.4**
PV6	-2.9	-5.2	**2.3**
PV7	-2.1	-2.2	**0.1**
PV8	-4.2	-3.2	**-1.0**
PV9	-6.4	-6.6	**0.2**

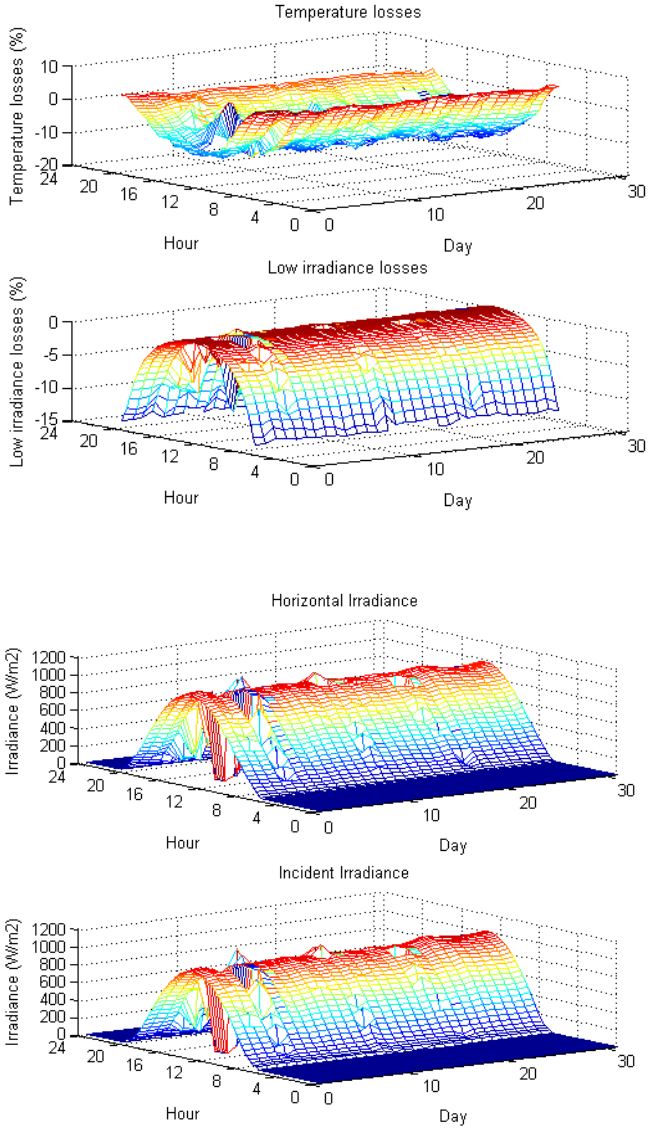




P2P analyses are available through Web services



Data analyses for PV plants operators and investors



SUMMARY

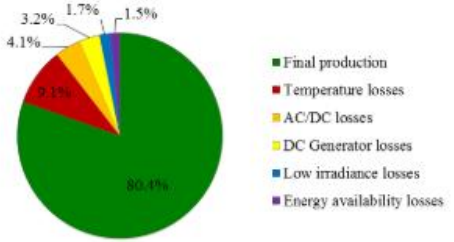
During the month of July 2013, the performance of the XXX PV plant has been in line with expectative.

a) Production results

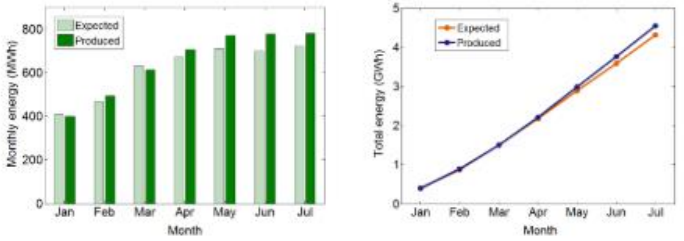
- AC Energy: 782,382 kWh
- Yield: 174.1 kWh/kW
- *PR*: 80.4%
- PR_{STC}: 90.0%
- Energy availability: 98.5%

b) No major incidences have been reported

c) Losses diagram



d) Historical energy data



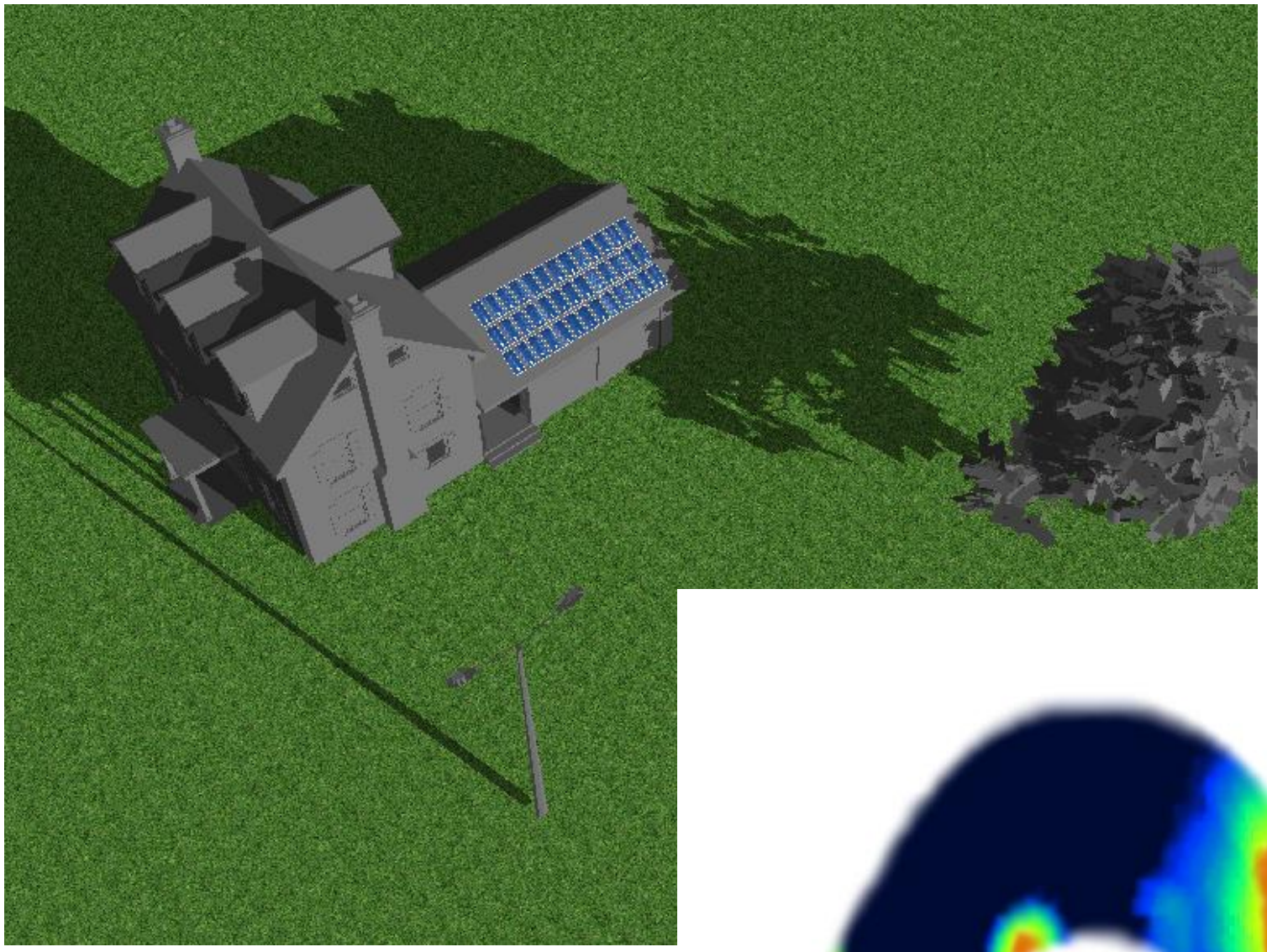
Prepared by:

R. Moretón
Web PV S.L.

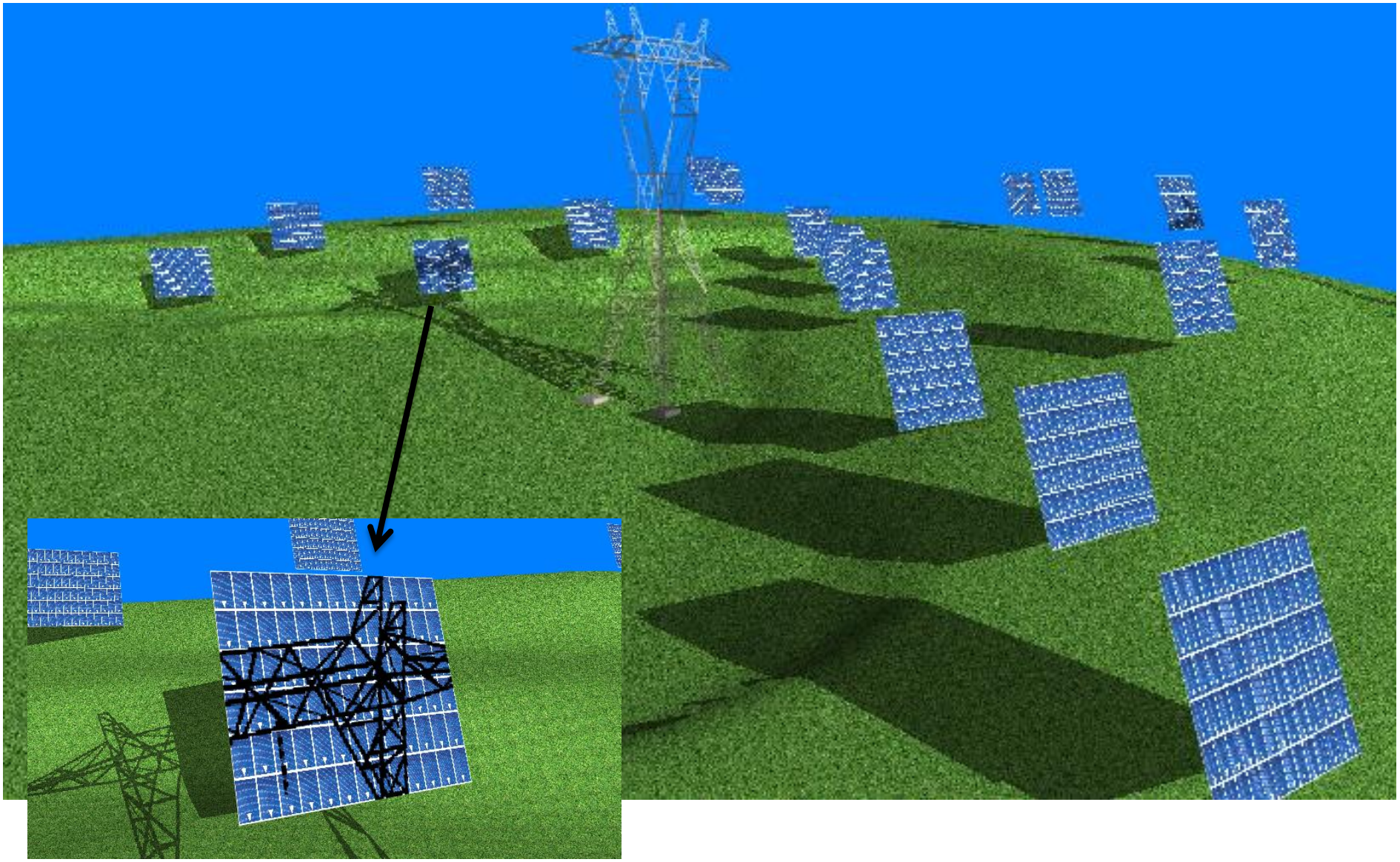
Reviewed by:

E. Lorenzo
IES-UPM

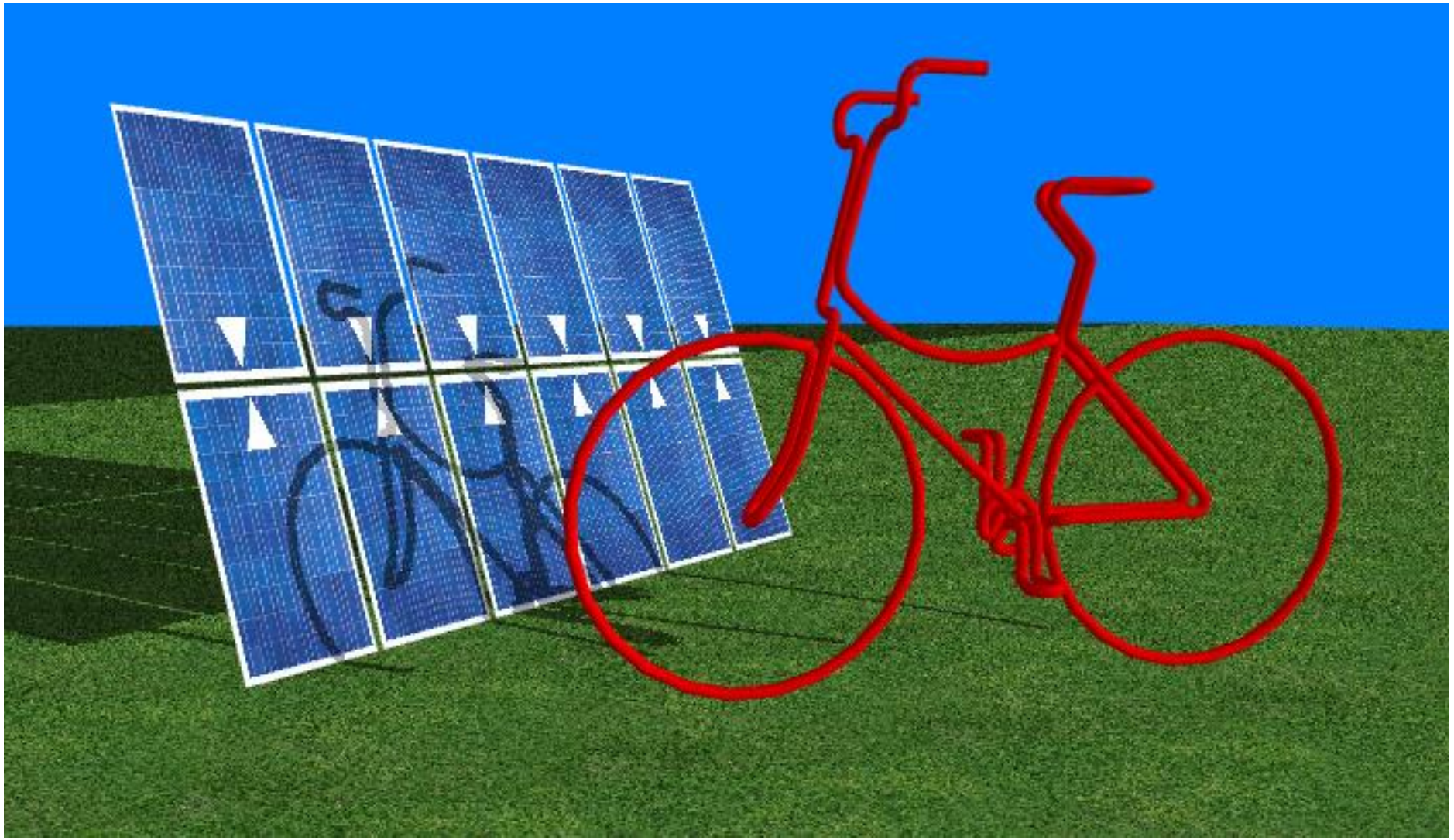
3D shading simulations – Residential PV with tree and streetlight



3D shading simulations – PV plants with trackers on uneven ground



3D shading simulations – A bike! (Useless, but we are in Amsterdam…)



3D shading simulations – Amsterdam RAI!!!

3D shading simulations: come listen to Jesus!

ORAL PRESENTATIONS 5CO.12

17:00 – 18:30 New Design and Planning Tools

Chairpersons:

G. Graditi
ENEA, Portici, Italy

C.2. Hansen
Sandia National Laboratories, Albuquerque, USA

5CO.12.1 Online Tool for Smart Selection of RES Solutions
I. Pinedo Pascua
European Commission DG JRC, Ispra, Italy

5CO.12.2 3D Simulation of Complex Shading Affecting PV Systems Taking Benefit from the Power of Graphics Cards Developed for the Video Game Industry
J. Robledo Bueno
WebPV, Madrid, Spain
J. Leloux & E. Lorenzo
UPM, Madrid, Spain

5CO.12.3 A Software-Based Planning Approach for Photovoltaic Power Plant Layouts
M. Bischoff
Siemens, Munich, Germany
I. Schüle & K. Plociennik
Fraunhofer ITWM, Kaiserslautern, Germany

5CO.12.4 A Physics Based GOES Satellite Product for Use in NREL's National Solar Radiation Database
M. Sengupta, A. Habte, P. Gotseff, A. Weekley, A. Lopez & M. Anderberg
NREL, Golden, USA
C. Molling
University of Wisconsin, Madison, USA
A. Heidinger
NOAA, Madison, USA

Contact

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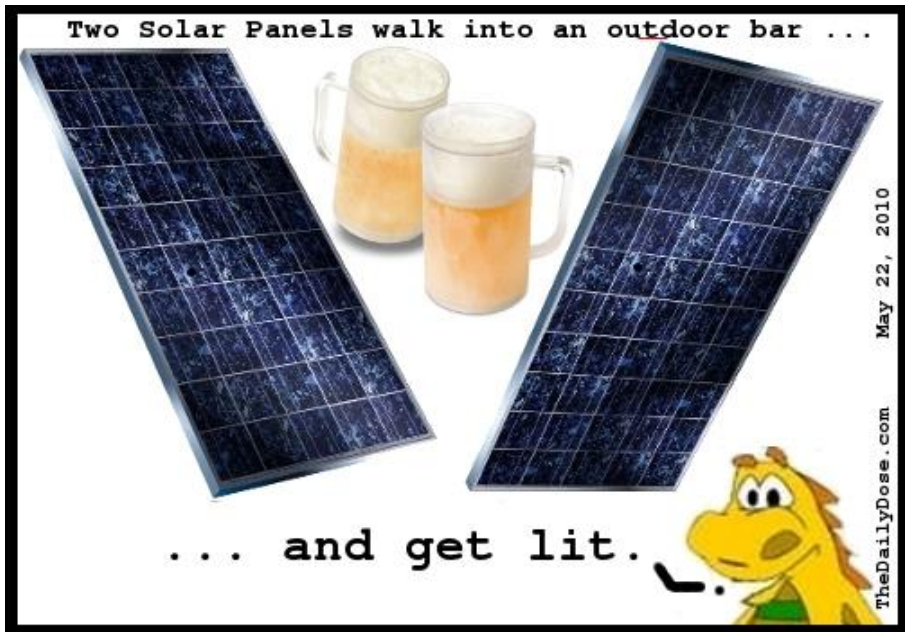
LinkedIn	**www.linkedin.com/in/jonathanleloux**



(we can also have a beer
to discuss all this…)